Framework for Estimating Productivity Benefits for Investment Analyses

Art Politano
May 11, 2001

Abstract:

The following paper provides a framework for estimating the productivity benefits of a planned technological improvement in the National Airspace System. The framework includes a step by step guide and tandem case study example to illustrate the application of the framework. These productivity benefits are shown to be readily estimated and readily translated to operating cost savings of an organization. Nevertheless, the reader should be aware that successful application of this framework requires the access and use of either FAA's staffing standards models, or some other equivalent workforce planning model.

Framework for Estimating Productivity Benefits for Investment Analyses

Art Politano

Preface

On September 9, the Operations Research and Analysis Branch (ASD-430) of FAA issued a draft of "General Guidelines for Conducting the Benefits Analysis Portion of An Investment Analysis.(1)" The intent of the general guidelines is to help the analyst and reader gain insight into the process and pitfalls that may be encountered when conducting a benefits analysis.

The "General Guidelines..." identifies four (4) phases and about 14 fourteen (14) steps (2). The phases include (a) the project and possibilities; (b) planning the analysis; (c) computing the benefits; and (d) post-implementation. The fourteen steps include detail guidelines, such as:

1. Describe project,
2. Identify the benefit category,
3. Describe the future operations with improvement,
4. Describe the future operations without improvement,
5. Identify the connection with the NAS Architecture,
6. Anticipate and discuss measurable benefits,
7. Develop a plan for benefit estimation,
8. Compute the productivity benefits,
9. Identify adverse consequences
10. Determine impacts on other programs,
11. Compute monetary benefits and the net present value (NPV),
12. Conduct risk analysis
13. Use metrics for post-implementation analysis
14. Apply statistical methods for post-implementation analysis.

This paper provides a general overview of the notion of productivity benefits and their general application to investment analysis. Following the overview, the paper includes a specific application of "General Guidelines for Conducting Benefits Analysis Portion of an Investment Analysis." The specific application provides an instructional illustration of how the fourteen steps might be applied to estimate the productivity benefit of the User Request Evaluation Tool (URET).

Overview of Productivity Metric

Background

In 1999, operating outlays for air traffic services totaled $ 5.6 billion, and estimated at 6.6 billion for FY 2001 (3). In developing a proposed architecture for the National Airspace System, FAA estimated that operating and maintenance expenditures would constitute the largest share of its expenses. Total personnel costs forecast for 2015 are estimated to be 30 percent higher than in 1998. (4). Some relief to address this increasing cost is likely to occur because the Wendell Ford Aviation Investment and Reform Act for the 21st Century makes available $ 6.6 billion in 2001; $ 6.9 billion in 2002; and $ 7.4 billion in 2003 (5).

The increasing staffing costs are due to the expected NAS workload increases. FAA forecasted (6) that between 1998 and 2015, the number of total aircraft instrument operations will increase from 68 million to 93 million. This is a total growth of 36.7 percent. The air carrier instrument operations will experience the largest growth-- 54 percent, growing from 14.3 to 22 million operations. The growth is based on socio-economic trends which show continued positive economic growth. To maintain safety, this increasing workload will increase the pressure on FAA to increase the staffing of the workforce.

To mitigate the increasing need for staff, FAA must invest in technologies which increase productivity. Increased operating and maintenance productivity are likely to relieve the operations funding pressure on the Federal Aviation Administration. It is only prudent, then, that productivity improvements of candidate technologies become a regular measure of benefit, when considering the funding priority of NAS improvements.

This benefits framework is designed to facilitate consideration of productivity in Investment Analysis.

Definition

O Productivity may be defined, in general, as:

The ratio of system input to output. The unit of measurement and improvement in the ratio are based on input and outputs that operate externally of the system being examined (7).

Measures

O In general, productivity measures can vary with aspects of output or input (8). In general productivity measures, have taken the form of:

- Labor productivity index, in terms of labor hours
- Direct labor cost productivity, in constant dollars
- Capital productivity, in either depreciation charges or the book value of capital equipment used
- Direct cost productivity, including all items of direct cost associated with resources used
- Total cost productivity, including all resource costs and depreciation costs, aggregated on a monetary basis,
- Foreign exchange productivity, including the amount of foreign exchange required,
- Energy productivity, in the amount of energy consumed
- Raw materials productivity, in terms of weight of product to weight or value of raw materials consumed

Typical generic formulations include (9):

$$\frac{AOMP / RIMP}{AOBP / RIBP} \times 100 \quad \text{or}$$

$$\frac{AOMP/AOBP}{RIMP/RIBP} \times 100$$

Where –

AOMP= Aggregated outputs of measured period
RIMP = Resource inputs of measured period
AOBP = Aggregated outputs of base period
RIBP = Resource inputs of base period

For benefit estimation, in the National Airspace System's Investment Analysis Process, the measure of productivity, best boils down to one of staff productivity. How much more effectively can NAS operators or customers do their job as a result of a new acquisition?

For example, measures of productivity for the NAS may include (10): the number of aircraft operations handled per controller per unit time for air traffic control; the number of pilot briefings completed by flight service station specialists per unit time for flight service staff; and number of facilities per technition and availability of facility per unit time for airway facility staff. These same metrics of productivity were adopted by the CNS/ATM Focus Team, an airline collaborative group whose concern was to explore metric concepts for evaluating air traffic service performance (11).

Data Needed and Availability

Data should be acquired for each investment analysis alternative to be analyzed, and for each of three cases. The cases would include: the most likely, low, and high estimates. Most likely, low and high estimates refer to each alternative's operating assumptions.

Table 1: Data Needs for Productivity Analysis

ATC Domain	Metric	Data
En-Route Center	Aircraft Operations per Controller	- Number of aircraft a controller can handle per 20 min period - Time per aircraft for controller communication, hand/arm activity, and scanning or looking time - Peak demand for a position (sector) - Aircraft occupancy time in each sector
TRACON	Aircraft Operations per Controller	-Number of areas and sectors per TRACON -Hourly traffic count for 90 percent busiest day per sector -ATC grade level Hours of operation for Tower Cab -90 % day airport operations -Ratio of IFR airport operations to total airport operations
Flight Service Station	Pilot Briefings per Specialist	-flight plan filing time -per aircraft contact for walk-in weather briefing -pilot briefing time -pre-flight clearance time
AF Maintenance	Number of Facilities per Technician Availability	-technician per facility -fraction of time NAS services are available -improvement in workforce management, remote maintenance monitoring, logistics, and engineering support.

Models and Their Application

Staffing standards are used by FAA to ensure that agency personnel are productively employed. A staffing standard is derived by a mathematical model which incorporates equations based on empirical measurements of the times required to perform a specific set of observable tasks (12). Staffing standards models are available for each of the major types of FAA facilities—air route traffic control centers (ARTCCs), terminal radar approach control (TRACON) facilities, airport traffic control towers, and automated flight service stations (AFSS).

To the degree that an Investment Analysis alternative can be understood well enough to translate its anticipated implementation into the time needed to accomplish work tasks, the number of future staff needed can readily be determined.

By comparing staff needs for a baseline case and for alternative investment analysis cases, it will be possible to determine the change in productivity at some future year. Moreover, since the salary per employee for each ATC domain is known, it is readily possible to translate the productivity increase into monetary savings. Productivity analyses have already been conducted for Controller Pilot Data-Link Communication (CPDLC (13)), Operational & Supportability Implementation System (OASIS (14)), User Request Evaluation Tool (URET (15)), and NAS Infrastructure Management System (NIMS (16)).

The experience, to date, has been that it may take between one to six months to complete a productivity analysis, with an average of, perhaps, three months.

Use in Investment Analysis: Caveats

We readily reduce the measure of productivity to monetary terms. However, we should understand that estimated monetary savings may not, in fact, be realized. Improvements in productivity may be hypothesized to save money because the job at hand may be perceived as not requiring as many staff. The reality of NAS operations is that staff is seldom cut back, rather staff is just used in other duties. Staff costs do not necessarily abate, because staff reductions are seldom made.

Alternately, what may happen is that as traffic increases, the existing work force has the capability to handle more and more traffic. As a result, staffing increases to accommodate increasing demand on the NAS is avoided. It is this avoided staff increase that can be more realistically realized. In this manner, staff productivity increases the capacity of the sector or airport and this may be translated in reduction of delay. Reduction of delay can be readily quantified.

Moreover, cost savings due to productivity increases is a step function rather than a continuous one. Increases in productivity reduce costs to the FAA only when a threshold of traffic demand is crossed, i.e. at these thresholds the number of controllers or technician required for a position increases.

Organizational Coordination:

FAA's staffing standard models are held, and principally applied by the Staffing Standards Branch (ATX-330) of the Air Traffic Resource Management Program. Susan G. Helzer is the Manager of the branch. She and her staff have been very agreeable and accommodating in running the staffing standard models for Investment Analysis. The coordination has followed a distinct pattern: ASD-400 translates the project to implications to amount of time to accomplish subtask work functions; ATX-330 runs the staffing standard model and determines the staffing required; ASD-400 determines productivity impact and cost implication of project.

Sources of Information:

The primary sources of information are: ATA-200 for traffic counts; ATX-300 for current staffing and projected staffing, and the IPT Program Offices for descriptive information on system implication to staff work tasks and performance.

Table 2: Availability of Data

ATC Domain	Data Availability
En-Route Center	-Enroute data is available from ATA-200 -Data availability will be a function of how much is known of project -Estimated from discussions with engineering or product staff -ATA-200
TRACON	-Discussions with field facility -Field input or TAF data -Estimate from discussions with engineering or product staff
Flight Service Station	-Estimate from discussions with engineering or product staff
AF Maintenance	-National Airspace Performance Reporting System -Estimate from discussions with engineering or product staff

Application of General Guidelines for Conducting Benefit Analysis for the Productivity Area, as applied to the User Request Evaluation Tool (URET)

This section provide an illustration of how the "General Guidelines..." (17) may be applied to the benefit area of productivity guidelines. The "General Guidelines..." identifies four (4) phases and fourteen (14) steps. This section follows those steps as they apply to the analysis of productivity benefits. This section relies heavily on a study of URET conducted in April 1998. The specifics of the URET Program have changed since 1998, but the benefits approach remains relevant because the function of the tool has not changed. Consequently, the use of this analysis, as a basis for these guidelines, is reasonable for illustration purposes, but current URET Program Information, such as deployment and timing, will vary.

Phase A: The Project and Possibilities

Step 1: Describe the project

URET is a key decision support tool in the en route architecture, as an element of Free Flight Phase 1. Free Flight Phase 1 is a limited deployment of controller automation decision support tools to obtain and evaluate early benefits to service providers and NAS users.

URET is a technology which will enable ATC computers to predict an aircraft's future position up to 20 minutes ahead, including its altitude. This is done using the aircraft's flight plan, performance, track, and wind data. This predictive capability will decide which aircraft are candidates for course revision based on estimates of heading, speed, altitude, altitude change, converging courses, delay requirements and the like. By means of regular and systematic checks for problems between future trajectories, URET will automate one important aspect of ATC decision making; namely, the detection of conflicts between aircraft, violations of protected airspace, and noncompliance to ATC-imposed traffic flow restrictions.

Step 2: Benefit category

The NAS Architecture reports that the costs to the FAA to build and operate the NAS will rise from about $7.5 billion in 1998 to $14.6 billion in 2015 (18). The overwhelming portion of these costs is expected to be for operations and maintenance, estimated at about 68 percent ($5.1 billion) in 1998 and rising to 78 percent ($11.4 billion) in 2015.

Given the cost to operate and modernize the NAS, a natural question is: how will URET affect the business of the FAA and will it help abate the cost of operating the NAS. The business of the FAA can be measured by the metric of staff costs. So, productivity can be translated into savings in staffing costs to operate the NAS.

We initiated the productivity analysis of URET to provide performance information for an investment analysis. The benefit area category of productivity lies under the “operational activity” regime (Figure 1), under aircraft movement. This is because URET is expected to facilitate the movement of aircraft by anticipating and avoiding aircraft routing conflicts.

An equally likely perspective is that of the user -- the business of the airlines and their operation in the NAS. The connection follows: improved productivity of controllers will translate to increasing the number of aircraft that can be handled by controllers in a congested sector. An increase in the sector capacity will translate to reductions in flight delays for the airlines. These reductions in flight delays can translate to monetary savings. While the application of URET can result in benefits in several metrics, savings in FAA staffing costs, reductions in delays, increases in efficiency, the focus of this analysis was on the metric of savings in staffing costs.

Figure 1, on the following page, illustrates the mechanism of how the NAS operates, and where URET will “physically” and operationally achieve its benefits. URET will achieve its productivity benefits in the “aircraft control practice” of FAA’s enterprise regime.

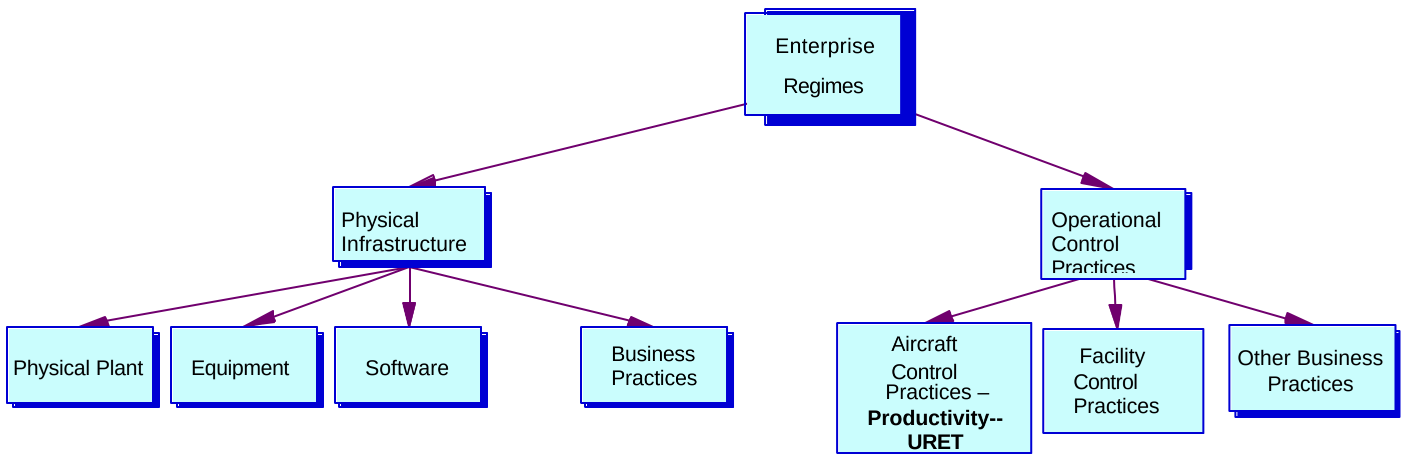

Figure 1: Location of the Productivity Area in FAA's Enterprise Regime (URET example)

Step 3: Future Operations with URET

URET may be able to help the controller team handle more traffic without loss of quality of service. Furthermore, the strategic control afforded by URET's longer look-ahead times is expected to result in more efficient resolutions of conflicts--that is, result in more timely and efficient types of maneuvers and fewer unnecessary maneuvers among aircraft. This will allow controllers to issue long-term clearances in heavy traffic conditions, thereby reducing workload and increasing ATC capacity.

The idea of using flight plan data (as opposed to track data, i.e., tactical conflict alert) for the purpose of detecting conflicts strategically is not new. Strategic control is a fundamental principle of ATC automation. To achieve this end, URET provides controllers with a predictive display to present them with the likely outcome of the current air traffic situation, most importantly automated conflict detection capabilities.

Step 4: Future Operations without URET

A controller is faced with the difficult task of mentally projecting ahead and comparing the aircraft flight paths based on paper flight strips. Given the difficulty of visually extrapolating over more than a minute or so, this is a difficult task, probably prone to miscalculation.

The D-side controller focuses on strategic conflict management, the R-side controller on tactical immediate traffic control. The future operational environment is likely to be an exacerbated version of today's environment. The operational environment will be exacerbated by the increasing volume of traffic to be handled by the R- and D-side controller teams.

Phase B: Planning the Analysis

Step 5: Connection of URET with the architecture

URET is a key technology in Phase 1 (1998-2002) of the National Airspace System's (NAS) modernization (19). It is expected that the URET will enable the ATC system to grant more efficient route changes to the airlines and move the NAS toward less structured free flight operations. URET is scheduled to become operational in the year 2000, reaching complete operating capability throughout the NAS by the year 2002 (20).

A quick review of the Capability Architecture Tool Suite and the National Airspace System Architecture shows that URET is an element of the en-route system. The operational concept has the NAS evolving to a flexible airspace structure, including dynamic airspace boundary restrictions, and flexible airspace structures. The en route architecture provides the basis for achieving the functionality defined in the operational concept. The en route architecture features revised flight data management, continuous access to expanded flight information, improved decision support tools, and improved surveillance processing with more accurate position, velocity, intent, and wind information. The en route architecture is driven by the need to sustain and replace the en-route automation hardware system. The first step includes the replacement of the Host/oceanic computer system (HOCSR) to solve the end-of-service-life problems. Subsequent steps include completing the display system replacement (DSR), providing next generation radar (NEXRAD) weather data to en route controllers, prototyping efforts of center terminal radar approach control (TRACON) automation system, and then the user request evaluation tool (URET).

To introduce early functionality, URET is now being executed as a new application on processors external to the Host/HOCSR, as part of the Free Flight Phase 1 project. Next, URET and controller Pilot Data Link communications (CPDLC) will be provided at selected ARTCCs as external processors in the 2000 to 2004 time frame. In the 2008 to 2013 time frame, the en route architecture will integrate URET and other en route systems (ATC decision support system; CTAS/TMA center terminal radar approach control automation/traffic management advisor) into the Enhanced En Route Oceanic System. URET then will integrate in stages into the en-route portion of the NAS.

In the first stage, URET functionality is being displayed for use by the D-side controller (planning). Full scale development of URET, termed CP for Conflict Probe, is expected to interface with HOCSR via HID/NAS Lan (Host interface device/NAS local area network) until evolution to the Enhanced En Route/ Oceanic System. The evolution of the en-route architecture in proceeding incremental steps and the capability of integrating URET functionality into the NAS is dependent on the progress in HCSR replacement, consequent Tech Refresh, and en-route functional enhancements (21).

Step 6: Anticipate and discuss measurable benefits

URET, at the time of our study, was being tested at Indianapolis and the Memphis Air Route Traffic Control Centers. In Indianapolis, URET was used specifically in the Pocket City Sector, a two controller, high altitude sector with between 18 to 35 aircraft per 15 minute period. This experimental use allowed us to directly observe controllers while they were using URET.

Where possible, the analyst should directly observe the use of the intended equipment acquisition. If this is not possible, the analyst may have to review the Requirements Document for the equipment, contact a potential manufacturer of the tool and ascertain what functionality may be produced, then contact potential users of the equipment to anticipate how work tasks and performance would change were the equipment used.

On two trips to the field (Indianapolis ARTCC), Operations Research and Analysis (ASD-430) and SETA staff met with 6 controllers who had received training on URET and had indeed used it to control live traffic. At the time, there were about 12 controllers which had received training, and our group of 6 was representative of the variation in training and experience of the larger group. While our stay spanned about 3 days, our access was limited to six controllers, given work shift arrangement. We conducted an interview survey to gain their insight on the potential impact of the tool on their operation in general and on productivity in detail. We surveyed the controllers on their direct experience using URET on the D (data)-side and their indirect experience working the R-side but interacting with the D-side controller.

To get a complete understanding of the operational impact of URET, a number of questions were posed to the six controllers that would elicit information useful to estimate productivity benefits. For example, we asked controllers to rate, on a scale of 1 to 7 (7 indicating considerable impact), URET's impact on those factors important in affecting controller workload (for example, mental effort, physical activities, number of interruptions and overall workload). We also asked controllers to estimate the time spent on each of three activities known to impact staffing requirements. These activities included: (a) all voice communication and hand-arm activity (e.g., keyboard, strip marking), (b) looking or searching for information on displays, and (c) position relief briefing. The frame of reference was 15 minutes. That is, we asked controllers: how much time they spend on activity (a), (b), and (c) in a 15 minute period.

Data controllers who worked with URET directly indicated that the time it took to perform "voice communication and hand-arm activity" dropped, on average, from 8.6 minutes to 4.2 minutes. The same controllers told us that the amount of time for voice communication was relatively stable, on average dropping from 3.6 to 3.2 minutes. By and large, the time saving was attributable to not using or marking flight strips, which is the main hand-arm activity.

Radar Controllers, who worked in sector teams with Data Controllers, also found that the time it took to perform "voice communication and hand-arm activity" also dropped, though more moderately. The time for Radar Controllers dropped from 8.4 minutes to 5.6 minutes. Once again, voice communication time was stable, but increased from 3.4 to 3.6 minutes.

For completeness, we also asked controllers about the time they spent on the second and third activity: "looking and searching for information," and "position relief briefing." Given a constrained period of 15 minutes, most controllers simply subtracted the time spent on "voice communication and hand-arm activity" from 15 minutes to arrive at the time spent on "looking." In addition, controllers assumed a nominal amount of time for position relief briefing. This was, in fact, what was reported. D controllers reported an increase of looking time from 5.4 minutes to 9.8 minutes, when URET was used. R controllers also reported an increase from 5.6 minutes to 8.4 minutes for the same circumstances. In addition, position relief briefing time was nominally assigned a one minute duration in both cases.

An interview survey proved quite useful in getting to the operational benefit of URET, fortunately we had access to an operational prototype system. Were one not available, then an alternate way of understanding the potential benefits to users would be: to describe the intended operation under the candidate technology to survey a sample of potential users about the probable impact of the technology, and then to arrive at a general consensus of the operational impact.

✓ **Tip:** Getting user's input is critical, because it is direct practical input. Averaging the input of a variety of users is even better, as is a consensus. In this way, differences in operating styles are averaged out.

❖ **Trap:** Care should be taken to be aware of conflict of interests on benefits and account for it accordingly. For example, a developer of a technology might suggest areas of benefit, but their estimation of amount should be suspect.

Step 7: Develop a plan for benefit computation

The plan for computing benefits followed the approach of translating operational changes to NAS productivity benefits and then monetizing these changes. The plan consisted of the following steps.

1. Identify the operational tasks that are impacted by the technology to be implemented. We showed how the efficiency of completing controller tasks have changed. We identified assumptions we used.
2. Estimate current or baseline operational performance related to identified benefit area. We did this by examining current staffing data from ATX-300.

3. Estimate operational changes induced by technology change and validate them with some independent observation. We did this through the survey of controllers.
4. Translate validated operational changes, and related assumptions, into ATX-300's productivity model inputs. This was done by working with ATX-300 staff and their consultant support.
5. Have ATX-300 run their en-route staffing standards model to identify staffing changes for both the baseline and experimental cases. Experimental cases consisted of Most Likely, and Best Case.
6. Translate the productivity changes to monetary terms. This was done by assuming a given level of controller performance and the salary for that controller.
7. Write-up preliminary results.
8. Brief preliminary results to operational colleagues, and obtain their feedback.
9. Look at the analysis objectively after a brief break in time, a week or two. We did this and were able to understand that the productivity benefits would be realized by not staffing up to accommodate increased traffic.
10. Write the final report or technical memorandum for the IA files.

We estimated that this project could take as much as two calendar months, it ended up taking about four calendar months. This time is measured from the decision to do a benefit analysis to the actual delivery of the report. Running the model was the single largest block of calendar time maybe two months. This was because ATX resources were occupied, at the time we wanted to conduct the study, so we had to wait for our turn. The second largest block was coordinating and conducting the field survey. This accounted for about another month. Analysis and report writing constituted the remainder of the time.

✓ **Tip:** Be sure to work with ATX-330 as early in the analysis as possible. Giving ATX enough lead time will allow them to better plan their resources to support a productivity analysis.

In terms of resources, it took two staff people (1 FAA, and 1 SETA), approximately two staff-months to complete the work, at about a half-time pace. Travel cost for the field survey were about two thousand dollars, $ 2000. The project was just nearing a JRC and so it had the visibility, and impact to garner the necessary travel resources and staff time.

We mentioned earlier that there were several areas of benefit that we could have focused on, such as reductions in staff costs, reductions in delay cost, increases in efficiency. We chose to concentrate on reductions in staffing costs because this was the most direct measure of productivity, and the approach was easiest to implement.

Phase C: Computing the Benefits

Step 8: Computing the Productivity Benefits, Applying ATX-300's En-Route Staffing Standards Model

Model Inputs

ATX-300's en-route model breaks down a controller's job into the time spent for each 15 minute period to perform standard tasks, and then on the basis of how many aircraft are expected to go through a sector, it calculates how many controllers are required to handle the expected workload. There are three primary actions that controllers perform: communicating, hand-arm activity (track ball movement, keyboard operation), and briefing a relieving controller. The primary URET benefit is that it relieves the use of a flight strip and strip marking, this most likely impacts the "looking" activity. To obtain how much time controllers spend doing each task, we conducted a survey of controllers and simply asked them to give us their estimate with and without URET's availability. We then averaged responses across all controllers, to get more credible numbers. We also observed controllers perform their tasks as another added measure of validity.

Lastly, we relied on a national staffing study conducted by ATX to compare the reasonableness of the input data. Empirical measurement of the times required to perform a specific set of observable tasks were made from time and motion studies. These data are periodically updated, the last update reflects time measurement data collected between October 1995 and February 1996 from eight air traffic control centers (22).

We observed that the use of URET did increase the amount of time spent by both Radar (R) and Data (D) controllers on "looking or searching for information." Our own observations led us to believe that while survey results indicated the amount of time spent on "looking" increased to fill the 15 minute period, the actual amount of time spent on "looking" appeared less than indicated. To consider this variability, we bound the time spent "looking" around an observed value. We did this by using the nationally reported "looking" time, activity (b), as the basis, and increased this value by 50 percent and 150 percent to account for the noted variability (the two cases).

For analysis, we used two cases. Each case varied by the amount of time controllers might spend regarding activity (b), looking time. Using the national data as a basis, we estimated that with URET, the D controllers may increase the amount of time spent on "looking" tasks from 2.9 minutes to 4.3 minutes for the best case scenario (50 percent increase in time reported) and 2.9 minutes to 7.3 minutes for the most likely case scenario (150 percent increase in time reported). Similarly with URET operating in the sector, R controllers increased the amount of time spent in "looking" tasks from 3.3 minutes to 4.9 minutes for the best case (50 percent increase) and 3.3 to 8.2 for the most likely case (150 percent increase). Since the 150 percent values are closer to what was reported by the survey, we labeled the 150 percent increase as the "most likely case scenario" and the 50 percent increase as the "best case scenario."

The best case scenario could have used any number between zero and the actual observed percent increase. For this URET productivity application, the best case had to have a number greater than zero because, compared with the baseline or reference case, the complexity of information of the screen increases for the same level of traffic. This increased complexity of information includes: trial planning information, Special Use Airspace dynamic status, and level and depiction of conflict track. Given the increased complexity of information on the screen, the value chosen for the best case was a 50 percent increase, chosen as an intuitive boundary of benefit range, in part because of controller feedback of false alarm indications on the screen.

- ✓ **Tip:** Selection of scenario cases is an important aspect of productivity analysis, and is best done uniquely for each new technology. Where available for future productivity analyses, representation of the best case should be informed by practical operational information, and well vetted discussions with users.

In response to our survey, controllers reported that the number of aircraft in Pocket City Sector could vary between 15 and 25 aircraft per 15 minute period, but the mode was 18 aircraft. Staffing studies of en-route centers found that the average number of aircraft handled by a two controller team, in a high altitude sector, is 18 aircraft. Accordingly, we used eighteen (18) as the average number of aircraft in the sector. Given the amount of time spent on each task by each R and D controller, we were able to calculate: (1) the amount of time each controller spent per aircraft, and (2) a new breakpoint for the number of aircraft each controller could handle in each sector type. The number of aircraft each controller could handle in a sector is known as the 15 minute interval capacity. The 15 minute interval capacity was the primary input from the Operations Research & Analysis Branch (ASD-430) to ATX-300.

The 15-Minute Interval Capacity is determined by the formula below:

$$\text{15-Minute Interval Capacity} = \frac{(15 - \text{Relief Brief Time})}{(\text{Communication, Hand-Arm Time} + \text{Look Only Time})}$$

For example, a Relief Briefing Time from a national study of .186 minutes per 15 minute interval, a Communication Hand Arm Time of .31 minutes per aircraft from the survey, and a Look Only Time of .46 minutes per aircraft from the national study yields the following:

$$\frac{(15 - .186)}{(.31 + .46)} = 19 \text{ Aircraft}$$

For information on the formula, refer to reference (23). Sample 15-Minute Interval Capacity input data are shown in Tables 3 and 4.

	Activity Time Loading per Aircraft Handled (minutes/aircraft)			**15-Min Interval Capacity** (aircraft handled)	
Controller Position	Communication Hand Arm	Look Only	Total	Individual Position	R and D Controller Team
R	.310	.460	.770	19	19
D	.230	.410	.640	23	

Table 3: Most Likely -- High Altitude Sector

	Activity Time Loading per Aircraft Handled (minutes/aircraft)			**15-Min Interval Capacity** (aircraft handled)	
Controller Position	Communication Hand Arm	Look Only	Total	Individual Position	R and D Controller Team
R	.310	.270	.580	25	25
D	.230	.240	.470	31	

Table 4: Best Case -- High Altitude Sector

For low altitude sectors, we assumed that the same relationships held as for the high altitude sectors, with the exception of the average capacity of the sector. For the high altitude, two-controller sector, the capacity of 18 aircraft was used, based on ZID and National observations. For the low altitude, two controller sectors, we use a capacity of 15 aircraft, based on national observations.

Model Operation

The staffing models are all operated by ATX-300, and they all follow the same approach. Future year staffing is estimated in a number of steps. First, activity counts for the 90th percentile busiest day (37th busiest day) are determined for the preceding year. The second step is to forecast for the current and any future years by multiplying the activity counts for the preceding year 90th percentile busiest day by the appropriate forecast factor from FAA' forecasting system. The third step is to insert the traffic forecasts and other relevant activity data into the forecasting model to forecast staffing levels for the 90th percentile target day. The last step is to annualize the daily facility staffing requirement.

Annualizing the daily facility staffing requirement is done in three substeps: first to get a 7-day facility operation; second to account for time off, and; third combining the first two factors. The 7-day operation is obtained by multiplying the daily staffing requirement, based on a 5-day workweek, by 7/5 or 1.4. The second adjustment, for time off, includes activities such as leave, training, annual physicals, and union meetings. The adjustment factor is 1.259, derived by dividing the total hours of work per year by the total hours available (2087) available. The total adjustment factor is the product of the preceding factors, yielding 1.76. The facility staffing requirements for the 90th percentile forecast day are multiplied by 1.76 to determine the final facility staffing number (24).

Model Outputs

The results of the En-route Staffing Standards Model were reported to the Operations Research and Analysis Branch in the form of staffing forecasts for all continental Air Route Traffic Control Centers, including all staffing specialties. The model forecast results for the most likely and best cases for 1997, 1998, 1999, 2000, 2002, 2005, and 2010 (25). For the intervening years of 2001, 2003, 2004, 2006, 2007, 2008, and 2009, we applied linear interpolation to obtain values. Linear projection was applied to estimate 2011 to 2015 values.

We projected that between the affected years (2000 and 2015), the controller workforce is expected to increase by 14 percent to keep up with the expected 32 percent traffic increase. Traffic will increase from 137.5 thousand to 165.2 thousand operations per day between 2000 and 2010 (26), and by projection to 181.1 thousand operations by 2015. With URET, the most likely case would only require a 10 percent increase for the same period, and the best case would require a 4 percent increase.

Figure 2 compares the anticipated growth in the controller workforce (CWF) for three different cases: (a) the “baseline” case, which shows the projected growth in CWF if URET were not deployed; (b) the “URET-most-likely” case shows the most realistic projection in the growth of the CWF if URET were deployed, and (c) the “URET-best-case” shows the most optimistic projections in the growth of the CWF if URET were deployed. Between 2000 and 2004, we projected that both the most likely case and the best case would allow the ATC System to accommodate increasing traffic without having to increase staff. Accordingly, there is no difference between the cases. At 2004, we projected that traffic increases would begin to overcome the productivity benefits of URET and it would then become necessary to increase ATC staff to accommodate growth. With the best case, traffic does not overcome the productivity gains until the year 2010. Between 2000 and 2010, URET's best case productivity improvements make staffing increases unnecessary. After 2010, even the best case productivity gains are overwhelmed and increased staffing is needed to accommodate expected traffic. In both the most likely and the best cases, traffic can be accommodated with abated growth in CWF.

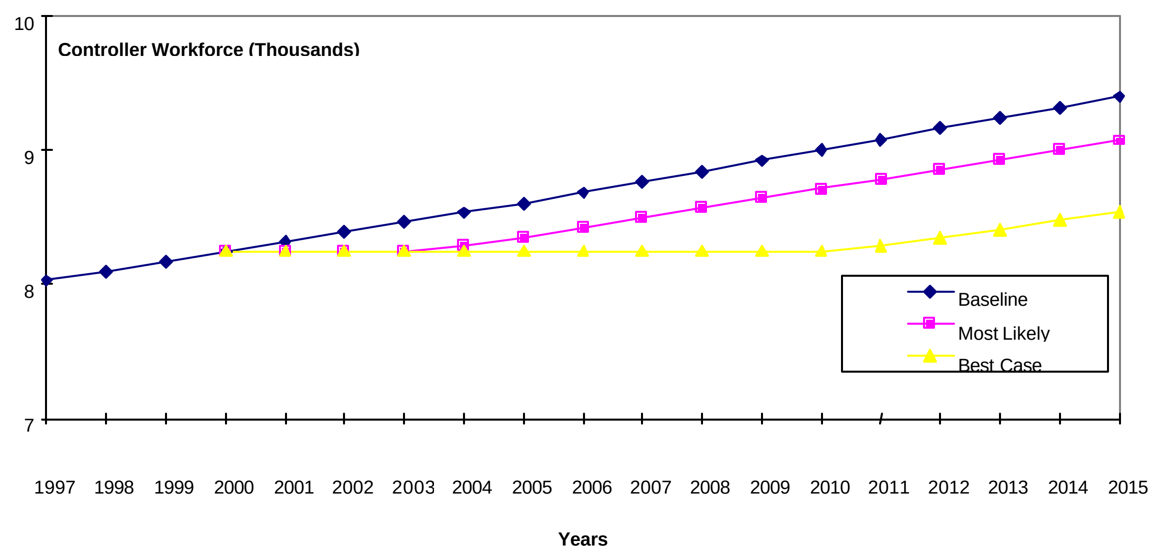

Figure 2: Growth in Controller Workforce for Three Cases

Step 9: Identify Unintended adverse consequences

Our visits to the field in the course of observing the URET resulted in the observation that during "busy" periods (based on inputs from one URET experienced controller and one URET trainee) the R controller directs most of his attention to the PVD and little, if any, attention to URET. One reason for disregarding URET output is that when busy, URET projects many false alerts because it is unable to probe transitioning aircraft accurately. In short, when traffic load is "heavy" the R controller appears to revert to a pre-URET (tactical) mode. The controllers' reported that they adopt this strategy because they simply don't have the time to check URET output when the display shows too many conflicts. Presumably, the need to validate displayed conflicts competes with other critical period activities. In short, the need to validate URET output requires too much mental effort and/or time to distinguish false alarms from "true" conflicts. Thus, URET has the potential to increase mental workload during critical periods, when workload is already high (and decrease it at workload troughs). The controllers simply adapted to URET's "weakness" by simply not attending to its output. The implication is that URET will be unable to provide productivity gains until the system is able to provide more accurate estimates of potential conflicts under all traffic conditions and consequently, controllers develop more confidence in its output.

Controllers recognized that URET is not equally useful under all traffic conditions. That is, the D controller relied on URET output quite heavily during periods of light to moderate traffic but not during period of heavy activity. Presumably, the controllers were able to calibrate their trust, that is, set their trust to a level corresponding to URET's trustworthiness and then use it accordingly. Controllers were aware, probably through training, that many of the displayed alerts were not reliable when aircraft were in (altitude) transition. Therefore when the D-side controllers did not trust URET outputs, they disregarded those outputs. This is significant because it suggests that the controllers, even with minimum tool experience, can assess the level of trust and confidence to place in the tool. In joint human-machine systems, a proficient controller is one who will get the most out of URET allowing him/her to devote more time and effort to compensate for any perceived weaknesses in URET.

We assumed that these observations were inherently factored in as part of the survey responses we obtained from controllers.

Step 10: Determine impacts of other programs.

The key issue here is to avoid double counting of benefits that other programs may claim. URET was uniquely applied at the time that the benefit calculations were made. Double counting then was not an issue.

Future versions (builds) of URET may rely on better weather data made possible by the Weather and Radar Processor, an acquisition called WARP. However, this application is not now funded adequately so its implementation is still in the future. The issue of double counting is probably more relevant for WARP than for URET.

Step 11 Compute Monetary Benefit and the Net Present Value (NPV)

Comparing the existing ATC operations with future ATC operations with URET deployed, it would be necessary to have on hand, on average, the equivalent of approximately 250 more controllers a year to handle the forecasted traffic. Introduction of the URET in the NAS can permit the accommodation of increasing air traffic operations, with modest increases in FAA staff.

The presumption here is that because the controller work force can handle more operations, the increase in the number of new controllers to be hired can be avoided. The cost of these deferred hirings is calculated easily. For this task, we use a cost of $96,000 per controller and a yearly inflation measure of 2.2 percent. We estimated a total potential savings of between $483 million and $1,006 million.

The table below provides a summary of monetary savings, year by year, which would be made possible by the use of URET. These savings are in constant 1997 million dollars.

Year	Most Likely	Best Case
1997		
1998		
1999		
2000	$0.0	$0.0
2001	$7.4	$7.4
2002	$15.2	$15.2
2003	$23.3	$23.3
2004	$28.1	$31.9
2005	$28.7	$40.7
2006	$30.1	$50.8
2007	$31.8	$61.5
2008	$33.4	$72.4
2009	$35.1	$84.0
2010	$36.9	$95.9
2011	$38.6	$104.0
2012	$40.6	$108.3
2013	$42.5	$112.6
2014	$44.5	$117.1
2015	$46.4	$121.7
Sum	$482.6	$1,046.8

Table 5: Productivity Benefits of URET

(in million 1997 $)

The yearly metric difference (project less baseline) values must be converted into present values, using standard, official FAA, DOT and Federal values (27). OMB Circular A-94 specifies that investment projects yielding cost savings to the Government and external social benefits be discounted at the base rate of 7 percent. On this basis, the most likely present values (1997) of benefits are $ 217 million for the most likely case and $ 437 million for the best case.

Step 12: Conduct Risk analysis

Risk was taken into account by using a base case, a most likely case, and the best case. This approach was used to bound the risks of the benefit case. We made the assumption that the benefits were likely to fall between the base case and the best case.

To calculate the overall risk of benefit estimation, we use a triangular distribution, where the Present Value for each of the base, most likely and the best cases serve as the minimum, most likely and the maximum point defining the distribution. Then, using the guidelines for benefit estimation in: "Special Topics in Investment Analysis on Cost and Benefit Estimates for Budgeting and Acquisition Program Baselines," we calculate the benefit estimate that has an 80 % probability of being overrun in actual program execution (28).

With a base of no change, a most likely case PV benefit of $ 217 million and a best case estimate of $ 437 million, a triangular distribution was constructed using the software Crystal Ball, version 4., manufactured by Decisioneering. Using a Monte Carlo simulation, and the triangular distribution specified, 2000 were run and the simulation stopped. A this point, $ 140 million was the value at which there was 80 percent probability that the value would be greater in actual program execution.

Phase D: Post Implementation Benefit Assessment

Step 13: Use metrics for post implementation analysis
Step 14: Apply statistical methods for post-implementation analysis

Assessment of benefits after implementation is a worthwhile enterprise because it provides necessary feedback information on the relevance of factors considered and the accuracy of the estimation methodology. The post-implementation assessment is best done about a year after deployment. This is so because the deployment bugs must be addressed, and the system must reach a state of equilibrium. Otherwise, the bugs may form a confounding factor in the remeasurement of benefits; or, benefit measurement will have changing results.

In its April 1999 report entitled "Air Traffic Control: FAA's Modernization Investment Management Approach Could Be Strengthened," the Government Accounting Office specifically suggested that FAA initiate post-implementation reviews. GAO asked that FAA initiate "post-implementation evaluations for projects within 3 to 12 months of deployment or cancellation to compare the completed project's cost, schedule, performance, and mission outcomes with the original estimates." FAA concurred with the request.

As of this writing, the Free Flight Phase One Program Office is in the middle of laying the foundation for measuring the benefit of partial implementation of URET.

References:

1. Cohen, Stephen, Guidelines for Conducting the Benefits Analysis Portion of an Investment Analysis, Federal Aviation Administration, September 4, 2000, Washington, D.C.
2. Ibid, pages 3-14.
3. Federal Aviation Administration, Administrator's Fact Book, Washington, D.C., April 2000 (Page 37).
4. Federal Aviation Administration, National Airspace System Architecture, Version 4.0, Washington, D.C. , January 1999 (Page 2-9).
5. HR- 1000-5, Section 103, January 24, 2000. (last correction 7/10/00)
6. U.S. Department of Transportation, Federal Aviation Administration Aerospace Forecasts: Fiscal Years 1999-2015, Washington, D.C., December 1999, FAA-APO-99-7.
7. Tomazinis, Anthony, R, Productivity, Efficiency, and Quality in Urban Transportation, page 17, Lexington Books, D.C. Heath and Company, Lexington, Massachusetts, 1975.
8. Mundel, Marvin, E, Improving Productivity and Effectiveness, page 11, Prentice Hall, Inc, Englewood Cliffs, New Jersey, 1983.
9. Ibid, page 11
10. Operations Research and Analysis (ORA), Federal Aviation Administration, Development and Application of Performance Metrics for the National Airspace System, Washington, D.C. , November 1997, Document Control Number R70400-01, pages 1-9 to 1-11.
11. CNS/ATM Focus Team, Airline Metric Concepts for Evaluating Air Traffic Service Performance, February 1, 1999.
12. Transportation Research Board, Special Report 250: Air Traffic Control Facilities, Improving Methods to Determine Staffing Requirements, Washington, D.C. 1997, Page 2.
13. ORA, Op. Cit., pages 4-5 to 4-11.
14. ORA, Op. Cit., pages 4-12 to 4-16.
15. Politano, Art, Preliminary Report 8: Productivity Assessment of the User Request Evaluation Tool, Operations Research and Analysis Branch, Federal Aviation Administration, Washington, D.C., April 1998.
16. ORA, Op. Cit., pages 4-16 to 4-18.
17. Cohen, Op.Cit., pages 3-13.
18. Office of System Architecture and Investment Analysis, "National Airspace Architecture." December 1997 Draft, Federal Aviation Administration, Washington, D.C. (pp. 16-17).
19. Ibid., pp. 4-30.
20. Ibid., page 41.

21. Office of System Architecture and Investment Analysis "National Airspace System Architecture," Version 4.0, January 1999, Federal Aviation Administration, Washington, D.C., pages 21-4 to 21-10.
22. Schmeidler, Neil and John D'Avanzo, "Data Link Productivity Impacts, En Route, Prepared for Investment Analysis and Operations Research," OMNI International, Contract DTFA01-96-Y-00045, September 22, 1997, pages 6-10.
23. Ibid, page 20.
24. Transportation Research Board, Special Report 250: Air Traffic Control Facilities, Improving Methods to Determine Staffing Requirements, Washington, D.C. 1997, Pages B-8 and B-9
25. Covington, Larry, Director, Office of Business Information and Consultation, Memorandum to Steve Zaidman, Director Office of System Architecture and Investment Analysis, Information: URET Evaluation, January 29, 1998, Federal Aviation Administration.
26. Covington, Ibid., pp. 2-10.
27. Federal Aviation Administration, Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, FAA-APO-98-8, June 1998, (or later). The latest version (as of May 2000) of this guide may be found at http://api.hq.faa.gov/apo_pubs.htm#ANCHOR98_10.
28. Federal Aviation Administration, Investment Analysis and Operations Research, Special Topics in Investment Analysis on Cost and Benefit Estimates for Budgeting and Acquisition Program Baselines, Revision 3, Page 2, August 4, 1998.